Dynamic backlight influence on motion blur measurement

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Abstract
Although commercially response time is still being used, but in the research community it now recognized that the motion blur needs to be estimated in order to give a fair characterization of a display's motion rendering capabilities. However, the dynamic backlight which has been added to improve contrast and black level of the LCD display could have an influence on the temporal properties of the display. This paper will show the dynamic contrast enhancement influence on the motion blur measurement and on the perception of the motion blur on two different displays.

1 Introduction
The LCD display technology has a number of inherent shortcomings that the display manufacturers are trying to compensate for. One such short coming has been the black level, which have been hard for the manufacturer to design the displays to reach really low values. With the introduction of LED backlight, this has enabled the possibility to locally reduce the light in dark regions to achieve really those low black levels. At the same time a bright region can get its brightness boosted, so that contrast becomes very high. What might not be expected is that this can lead to unexpected negative side effects, such as e.g. noticeable large area light change when region is suddenly changing from one colour or gray level to another.

Another short coming of the LCD display that has been very much in focus the recent years is the motion blur. It has been recognized that the temporal behavior[1-5] of the update of a pixel is very important for the motion blur characteristics of a display. With the introduction of a dynamic backlight that will adjust its levels according to the content currently displayed on the screen, there will be an influence on the temporal characteristics of the display, which may have in influence on the motion blur behavior of the display. This can be especially noted on TVs and displays with full RGB LED backlight units. It could even be hard to disable the local dimming in the set-up of the displays and it might remain on to some extent. An additional difficulty especially for TVs, but increasingly also for desktop displays, is the growing number of display modes that have different image characteristics. This makes it hard to choose the display mode for testing since not all can be scrutinized in detail. It seems like the number of modes and settings are a competition tool and the more you have of them the more sophisticated TV and the higher prices.

The main focus of this paper is the influence of dynamic backlight on the motion blur characteristics of LCD TVs. Two sides of the problem with covered. One side is the influence on the measurement and the other side its influence on the perceived motion blur.

2 Method
The study consisted of a measurement part, which tries to estimate the motion blur characteristics of the display. It also consisted of a perceptual study to compare the impact of the dynamic backlight on the perceived motion blur.

2.1 Apparatus
Two LCD-TVs with RGB LED backlighting of different brand were used in the study. One was 42 inch, which we will refer to as DUT1, and the other was a 40 inch, which will be called DUT2. They were both Full-HD with a native resolution of 1920 by 1080, which was also the resolution used in this study. The frame rate was set to 60 Hz. The displays were driven with a computer with a 64 bit Windows Vista, using Intel Core 2 Quad processor (Q9550 at 2.83 GHz) with 8 GByte of primary memory. The graphics card was an ATI Radeon HD4870 X2 with 2 GByte of memory. Care was taken to turn off all special processing on the two displays, except for the dynamic backlight (named differently on the two TVs), which was turned on when this feature was tested.

2.2 Motion blur measurements
A sequence of gray patches ordered to measure 20 transitions from one gray level to another among five, was used for these measurements,. Each gray patch was displayed during 20 frames. The following gray levels have been used: 0, 63, 127, 191, and 255.

The light intensity emitted by the display was read by a photo diode positioned in close contact with the screen surface. The photo diode was surrounded by black velvet in order to reduce any scratches to the display surface and to shield any ambient light reaching the photo diode. The photo diode (Burr-Brown OPT101 monolithic photodiode with on chip transimpedance amplifier) has a fast response (28 µs from 10% to 90%, rise or fall time). The signal was read by an USB oscilloscope EasyScope II DS1M12 "Stingray" 2+1 Channel PC Digital Oscilloscope/Logger from USB instruments. The accuracy of the instrument has been tested with a LED light source connected to a function generator. The sampling time used for these measurements was 0.1 milliseconds. The Moving Edge Temporal Profile (METP) was then computed in the same way as described in Tourancheau (2009)[4]. By taking the time difference between the 10% and 90% level of METP the Blur Edge Time (BET) was obtained. This has been shown to be good characterizations of the motion blur behaviour by several authors [1-5].

2.3 Perceived blur
A blur matching experiment, similar to that performed by Tourancheau et al (2009)[5], was performed to get a relation between the measured blur and the corresponding experienced blur by human observers, with and without dynamic backlight. The observers adjusted the width or the blur of a stationary edge

to match the blur of a moving edge. The transitions used were: 0 to 255, 127 to 255, 191 to 255, 255 to 127, 255 to 191 and 255 to 0. These were randomly presented with the different speeds: 7, 10, 13, 16 pixels/frame. The viewing distance was 2.08 picture heights.

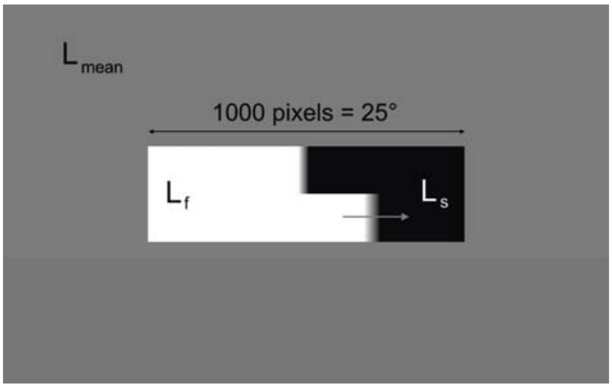

Figure 1: Image of the screen of the blur matching experiment.

3 Results

3.1 Motion blur measurements

A number of grey level transitions have been recorded. The effect to the dynamic backlight is most noticeable in transitions between a quite dark to a bright level.

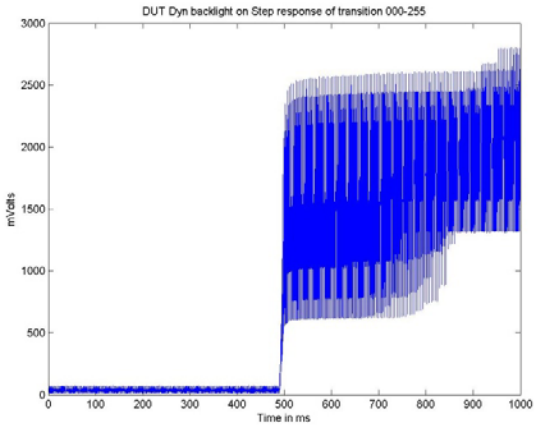

Figure 2: The raw response time data from the transition 0 to 255, when the dynamic backlight is on

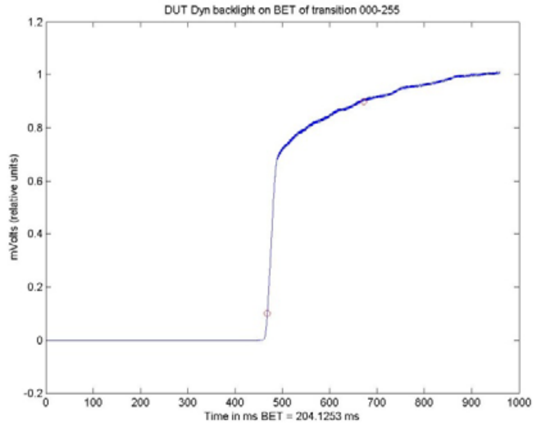

Figure 3: The METP of the transition 0 to 255, when dynamic backlight is on.

In Figure 2, the raw step response data of a transition from 0 to 255 from a display with the dynamic backlight on, is shown. The increased brightness can be noted. Figure 3 shows the same transition when transformed into MESP. Here the increase is very clearly visible. As a comparison, in Figure 4 and 5, the transition is shown when the dynamic backlight is off.

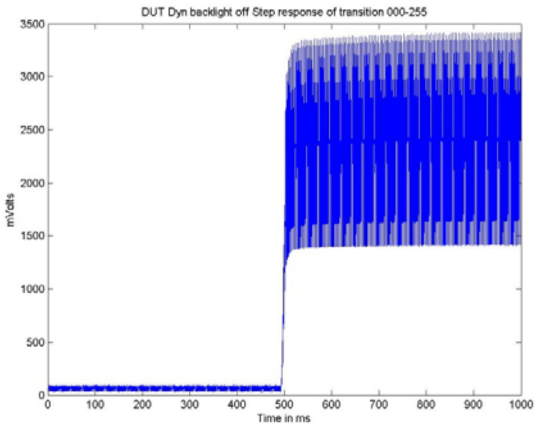

Figure 4: The raw response time data from the transition 0 to 25, when the dynamic backlight is off

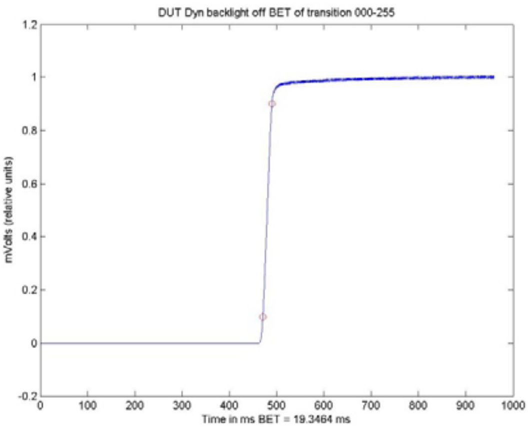

Figure 5: The METP of the transition 0 to 255, when dynamic backlight is off.

In this example the measured BET is different with about 185 ms! We measured the BET for 20 transitions with and without the dynamic backlight on, see Table 1, for the two DUTs used in this study. The grey levels used were: 0, 63, 127, 191 and 255.

Table 1: BET estimates in ms for 20 transitions with and without the dynamic backlight on.

Transition	DUT1-Off	DUT1-On	DUT2-Off	DUT2-On
000-255	21,81	128,04	19,35	204,13
255-191	17,92	155,16	17,54	105,26
191-255	16,37	146,4	16,15	258,14
255-127	17,3	18,36	17,96	22,61
127-255	20,44	90,24	16,42	263,84
255-063	17,5	17,94	19,52	20,31
063-255	21,52	128,94	17,43	206,69
255-000	14,78	14,79	17,92	18,52
000-191	30,07	145,71	26,21	102,47
191-127	19,44	16,64	18,48	20,8
127-191	33,32	91,73	18,15	249,14
191-063	18,7	16,94	19,41	20,22
063-191	31,43	146,93	21,21	94,3
191-000	14,61	12,74	17,69	18,41
000-127	27,72	18,31	37,62	29,48
127-063	22,22	16,38	20,34	19,69
063-127	20,36	16,56	28,23	22,93
127-000	14,39	10,47	17,8	17,76
000-063	51,1	26,69	41,99	42,67
063-000	14,63	10,26	17,83	17,59

There are very large differences for several transition and they goes as large as 247 ms.

3.2 Perceived blur

A blur matching experiment was performed, as described above with 10 test persons (9 male and 1 female). The age range was between 27 to 62 years with a mean age of 40 years. The difference in mean perceived blur for dynamic backlight off and dynamic backlight on is shown in Figure 6. The backlight on shows a slight, but as shown below a non-significant increase in perceived blur width. In Figure 7, the perceived blur widths for the different transitions are presented. The blur width with the dynamic backlight on is slightly wider than for the dynamic backlight off. The differences are slightly larger for large dark to bright transitions, but the variability is also larger here. The perceived blur increases linearly with the speed, see Figure 8, as have been shown by earlier studies e.g. Tourancheau (2009)[5]. Here, a slight increase in the coefficient of slope for the dynamic backlight turned on. None of these effects are statistically significant.

The difference in perceived blur width for the two DUTs is shown in Figure 9.

A mixed model of analysis of variance (ANOVA) was performed and the increase in blur width due to the dynamic backlight was not found to be significant on the 95% confidence level i.e $F(1,0.9) = 2.35$ $p = 0.38 > 0.05$. The significant main effect ($p < 0.05$) were the Transitions ($F(5,5.5) = 5.04$), Display ($F(1,6.8) = 6.72$), and the Speed ($F(3,3.4) = 23.9$). There were no two-way or three-way interactions involving the backlight that were significant.

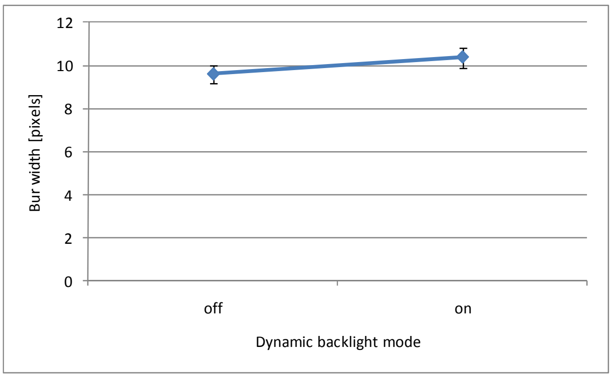

Figure 6: The mean perceived blur width for dynamic backlight off and dynamic backlight off.

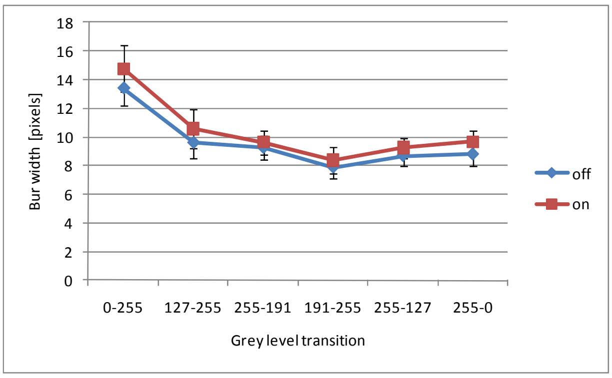

Figure 7: The mean perceived blur width broken down over the different transitions.

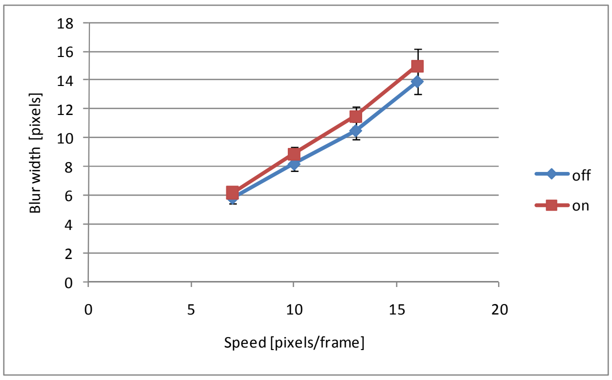

Figure 8: The mean perceived blur width broken down over the different speeds of the moving edges.

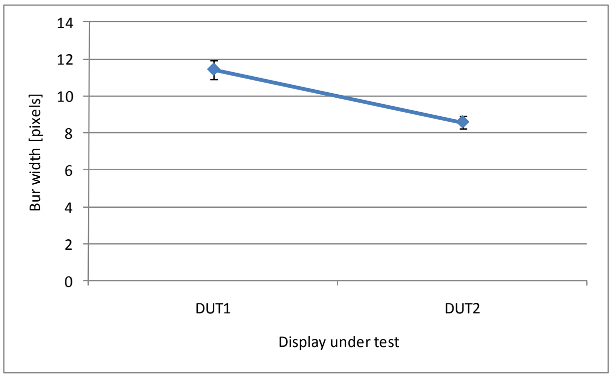

Figure 9: The perceived blur width of the two displays.

4 Discussion

The blur matching experiment does not show that the perceived blur corresponds to the large differences found when measuring BET, between the cases were the dynamic backlight is turned on or off. The large differences shown in this investigation is partly due to the long measurement time that was used to obtain the BET data. This was done intentionally to capture the dynamic behavior of the backlight. However, since there is a smooth transition between change due to LCD crystal change and that of the dynamic backlight it will be very difficult to select a suitable cut-off time when estimating BET with the dynamic backlight turned on.

At present there are no criteria to select the most suitable display mode for testing if not all modes shall be tested, which is time consuming and expensive. It is hard to know exactly how the settings of the different parameters will affect the results of the motion blur measurements and other imaging parameters and some settings may work against each other.

The motion blur characteristics are likely different in the different display modes. It is probably more important for movies and sports. Since there are a number of display parameters that can be altered automatically or by the user, a number of these setting will affect the result of a motion blur measurements. In a short pre-study, a LCD-TV with full RGB LED back-light unit was evaluated. It must be said that the names of the different modes, the names of the parameters that can be altered, the amount of the levels etc can be quite confusion and there seems to be no general agreement between different manufacturers. In addition when the names are translated into different languages a new level of confusion is introduced. In many cases a setting does not always adjust what could be expected, e.g. when the local dimming is supposed to be disabled it could still be working in an unknown way. The gamma curve is another parameter that often is set differently in different display modes. It is also a parameter, which setting will likely affect the result of the motion blur. In this pre-study we tried to set the gamma curve as close as possible to the sRGB with the help of a calibration tool. It was very hard because firstly there were always some grey levels that refused to collaborate and secondly, the display itself changed the settings after a period of time. It was not known how the look-up table was programmed.

5 Conclusions

We have shown in this paper that influence of dynamic backlight on the measurements of blur i.e. BET is considerable.

The perceptual experiment shows that there is a slight influence of the dynamic backlight. That is, edges are perceived with just slightly more motion blur. However, this effect was not significant in this study.

The conclusion and the recommendation of this study is that the motion blur measurement should be performed with the dynamic backlight turned off.

Acknowledgements

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